Alternative: Groundwater Desalination

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1. Summary of the Alternative

Desalination is a water treatment process that converts brackish or saline water to fresh water by removing dissolved minerals (e.g., sodium and chloride ions) from the water. Where supplies of brackish or saline water exist, desalination can be used to yield potable fresh water. However, because of its relatively high cost, desalination is generally only chosen when supplies of fresher water are not available.

Groundwater within the Jemez y Sangre study area is generally of excellent quality and is obtained primarily from sand and gravel aquifers of the Tertiary Santa Fe Group (Wilson and Jenkins, 1979). However, brackish groundwater does exist in some parts of the study area. For example, total dissolved solids (TDS) concentrations in groundwater in much of the South Galisteo Creek sub-basin exceed the New Mexico Water Quality Control Commission (NMWQCC) groundwater standard of 1,000 mg/L (DE&S, 2001). These high TDS concentrations are associated with groundwater from the Paleozoic and Mesozoic bedrock aquifers that underlie the area, and groundwater from these aquifers is simply too salty to be used without desalination treatment. Other locations within the Jemez y Sangre study area where slightly to moderately elevated TDS concentrations occur in groundwater include (1) portions of the Los Alamos well field (Blake et al., 1995), (2) isolated wells within the City of Santa Fe's Buckman well field (DE&S, 2001), and (3) the western side of San Ildefonso Pueblo near the boundary between the Tesuque and Los Alamos sub-basins (DE&S, 2001).

However, water rights would be required to divert the brackish water in these areas, and therefore, desalination would not create more water, unless water is piped in from other regions. Desalination can be used to treat existing water supplies, but is not considered an alternative for meeting new demands in the region.

In addition to treating naturally brackish groundwater, desalination processes may be an important tool in the reuse of treated wastewater effluent. Wastewater typically contains higher TDS concentrations than the source water, and repeated reuse results in a buildup of dissolved salts. Desalination can be used to counter this salt buildup. Desalination may offer additional benefits such as removal of organic compounds and pharmaceuticals from reclaimed water.

2. Technical Feasibility

Desalination plants are used commercially to provide fresh water for many communities around the world; thus the technical feasibility of desalination has been proven. Approximately 13,600 desalination units in 120 different countries currently produce 26 million cubic meters of fresh water each day (Reuters ENN, 2001). The Middle East region has approximately 50 percent of the desalination capacity because fresh water supplies are scarce in that region (Gleick, 1998; Buros, 1999). The United States has approximately 10 percent of world desalination capacity (U.S. Congress, 1988).

Two main types of desalination processes are currently in use: (1) membrane methods and (2) thermal methods. The most common membrane process is reverse osmosis (RO), whereby pure water passes through a semipermeable membrane under pressure, leaving the dissolved salts (minerals) behind in a more concentrated brine solution. A related technology is electrodialysis (ED), which uses charged electrodes to cause dissolved ions to pass through semipermeable membranes, leaving behind water of lower salinity. Nanofiltration membranes have also been demonstrated to remove salts, though not as completely as RO. The most well known thermal process is distillation, where saline water is heated to increase its vapor pressure, and subsequent condensation of the resulting water vapor yields fresh water.

Existing desalination plants consist primarily of RO, ED, and multistage flash distillation units (Table 1). The production capacity of membrane and thermal process plants is presently nearly equal, but most older plants are distillation units, so the total operating capacity of membrane plants will likely increasingly exceed that of thermal units (Buros, 1999). Where brackish water containing less than 10,000 parts per million (ppm) dissolved salts is available, membrane

Table 1. Selected Membrane Desalination Plants Operating in the Western United States

City/Name	State	Startup Year	Plant Capacity (mgd)	Process Type [a]	Recovery Rate [b] (%)	Feedwater Type [c]	Product Water Type [d]
Buckeye	AZ	1989	0.9	EDR	80	BW	DW
Chandler	AZ	1997	2.3	NF / RO	88	WW	GWI
Bolinas	CA	1996	0.2	MF	80	IW	DW
El Segundo	CA	1996	20.0	MF / RO	70	WW	IRR / IND
Marina	CA	1996	0.3	RO	40	SW	DW
Oceanside	CA	1994	2.0	RO	75	BW	DW
Riverside	CA	1990	5.4	RO	76	BW	GWI
Saratoga	CA	1994	5.0	MF	93	IW	DW
Torrance	CA	1993	1.3	RO	80	BW	IRR / IND
Tustin	CA	1996	3.0	RO	84	BW	GWI
Water Factory 21	CA	1977	5.0	RO	85	BW / WW	GWI / DW
Las Animas	CO	1996	1.0	RO	50	BW	DW
Washington	IA	1993	1.9	EDR	88	BW	DW
Wallace	ID	1998	1.2	UF	80	IW	DW
Froid	MT	1995	0.1	RO	88	BW	DW
Sherman	TX	1993	6.0	EDR	85	IW	DW

Source: http://www2.hawaii.edu/~nabil/mdpow.htm#state

mgd = Million gallons per day

[a] EDR = Electrodialysis reversal
MF = Microfiltration
NF = Nanofiltration
RO = Reverse osmosis
UF = Ultrafiltration

[b] Product water/feed water

[c] BW = Brackish water
GW = Groundwater
IW = Impaired water
SUR = Surface water
SW = Seawater
WW = Wastewater

[d] DW = Drinking water (potable water)
GWI = Groundwater injection
IND = Industrial water
IRR = Irrigation water

processes (RO or ED) are generally the preferred technologies for desalination. ED tends to be more economical at salinities less than about 3,000 ppm, whereas RO is preferred at salinities between 5,000 and 10,000 ppm (U.S. Congress, 1988).

Historically, desalination has suffered from a non-technical bias against technologies that are perceived as innovative or unproven (U.S. Congress, 1988). Engineers charged with designing water treatment plants tend to favor “tried and true” conventional water treatment techniques. However, with increasing numbers of desalination plants coming online worldwide, this perception is changing.

3. Financial Feasibility

Several considerations influence the cost of desalination per volume of freshwater produced, including (1) feed water salinity, (2) energy costs, and (3) economies of size. The major categories are capital costs and operation and maintenance (O&M) costs. In addition, any economic evaluation of the total cost of water delivered to a customer must include costs for water distribution and costs for compliance with environmental regulations (Section 6).

Costs rise significantly with increasing salinity of the feed water, and the cost of desalting seawater (TDS=35,000 mg/L) is three to five times higher than the cost of desalting lower-salinity brackish water from the same size plant (Buros, 1999). Therefore, it is advantageous to make use of the freshest feed water available. Reverse osmosis plants appear to be the preferred choice for desalting brackish water in most small to medium-size communities in the United States. This is due to their simpler operation, lower energy consumption, and resulting lower fresh water unit costs as compared with other desalination methods (Glueckstern, 1999). The overall cost of fresh water from a reverse osmosis plant is often less than half of that produced by means of distillation, although the process has higher up-front investment costs compared to thermal processes. As technical advancements of membrane processes improve their cost and efficiency, they will continue to be the preferred choice for new desalination plants. Given that the groundwater underlying parts of the Jemez y Sangre study area only marginally exceeds water quality TDS standards, it appears that ED or RO would most likely be the preferred desalination technologies. Depending on feedwater quality, some pretreatment may be required prior to desalination by RO or ED.

All desalination processes require large amounts of thermal or electric energy. A finite minimum amount of energy is required to separate pure water from a saline solution. For seawater, for example, this minimum energy is approximately 2.65 kilowatt hours (KWH) per 1,000 gallons of fresh water produced (Cordes and Shaeffer, 1973). However, because of inefficiencies that exist in any real process, the actual energy requirements for desalination systems are substantially higher than this theoretical minimum value. In practice, energy costs often represent 50 to 75 percent of operating costs (Mesa et al., 1996). With generally the lowest energy requirements, membrane processes are more attractive in many instances, compared to distillation plants (Sackinger, 1982; Glueckstern, 1999), and rising energy prices tend to increasingly favor RO or ED.

Economies of scale arise when increases in the plant size (gallons of water produced per day) bring decreases in the unit fresh water cost. Economies of size are evident in all desalination processes, but to different extents. RO exhibits the smallest economies due to size, while distillation processes show the greatest economies of size. O&M costs are not subject to economies of size, but are directly affected by the quality of the feed water (Morin, 1999).

Costs (in 1985 dollars) for desalination of brackish water (<10,000 ppm) using RO or ED are in the range of $1.50 to $2.50 per 1,000 gallons of water produced, or approximately $500 to $830 per acre-foot (U.S. Congress, 1988). These costs do not include distribution costs or the cost of brine disposal. Because of economies of scale, costs are higher for small-capacity plants. At present, costs for traditional water supplies generally remain lower than the total cost of desalinating water. However, the gap between the two might be reduced by (1) reductions in the cost of desalination (e.g., by reducing energy costs or increasing energy efficiency), and/or (2) increases in the cost of traditional water sources.

Increasing demands for fresh water worldwide should result in continued improvements in desalination technology. Improved desalination technologies will increase the performance ratio (the ratio of fresh water to the amount of energy consumed) and hence lower the unit costs of producing potable water. Reduced energy costs would likewise make desalination relatively more attractive. Recent investigations have focused on the use of renewable energy to provide the required power for the desalination process, with the most popular renewable source being solar energy. Another approach is the use of dual-purpose plants, where the desalination plant is connected to an electric power generating station and uses the waste heat from that station as an energy source (Buros, 1999; Goosen et al., 2000).

Solar desalination systems are simple and easy to operate and maintain, and also reduce pollution by not using fossil fuels (Voivontas et al., 1999; Chaibi, 2000). In locations with abundant sunshine, such as New Mexico, solar desalination is a potentially viable option, especially for small-scale plants in remote locations. Indeed, RO of brackish water (if available) using solar energy is potentially the cheapest way to provide new fresh water resources in remote areas (McCarthy & Leigh, 1979; Voivontas et al., 1999). At present, solar desalination worldwide is restricted to remote areas needing smaller desalination systems.

Increases in the cost of traditional water sources will make desalination increasingly attractive. Costs of traditional water sources may rise in the future for a number of reasons:

- Increasing levels of treatment being required to meet more stringent water quality standards

- Demand for fresh water outpacing supply

- Environmental concerns reducing quantities of traditional water sources available to communities

- Alteration of existing pricing schedules to reflect true costs of water

Determining the true cost of water can be difficult, and if known, true costs would often be significantly higher than the costs charged to consumers. When compared with true costs of traditional water supplies, desalination would immediately become more competitive than it appears based on prices currently charged for water from conventional sources.

4. Legal Feasibility

The legal restraints arising in the context of the groundwater desalination are minimal. In New Mexico, the State Engineer has no jurisdiction over aquifers that are 2,500 feet or more below the surface of the ground and contain nonpotable water (defined as water containing more than 10,000 parts per million TDS) (NMSA 1978, §72-12-25). Thus one way to acquire new, unappropriated water is to tap nonpotable water.

Before a well can be drilled in such an aquifer, a “notice of intent” to drill such a well must be filed with the State Engineer and published in a newspaper in the county in which the well will be located. Such notice must state the location and depth of the proposed well, the purpose for which the water will be used, and the estimated amount of water that will be used. The proposed well can be drilled 10 days after publication of the notice (NMSA 1978, §72-12-26).

Any person claiming impairment of existing water rights due to an appropriation of nonpotable water may bring an action in state court (NMSA 1978, §72-12-28). Such impairment may be subject to a plan of replacement pursuant to state law (NMSA 1978, §72-12A-4). Once acquired, nonpotable water that will be used for municipal purposes must be treated to comply with Safe Drinking Water Act standards (42 U.S.C. 300f *et seq.)* and New Mexico’s drinking water regulations found at 20 NMAC 7.1.

Since the majority of the water in the region contains less than 10,000 TDS, it falls under OSE jurisdiction. New appropriations for groundwater require submission of an application for a permit to the OSE (NMSA 72-12-1). However, the groundwater in the region is generally considered to be connected to surface water, which means that no unappropriated water is available for new permits. In such cases, the State Engineer allows only the transfer of perfected consumptive water rights. Consequently, the acquisition of water rights in a basin where all surface water effects of groundwater pumping must be offset can only occur through the marketplace between a willing seller and a willing buyer. In addition, such a transfer can occur only after publication and notice and after a determination that the proposed appropriation and its point of diversion and place and purpose of use will not impair existing water rights, will not be contrary to the conservation of water, and will not be detrimental to the public welfare.

The legal restraints associated with the disposal of brine include the necessity of obtaining either a groundwater discharge permit pursuant to the state Underground Injection Control Program or, if discharge is to surface water, a federal National Pollutant Discharge Elimination System (NPDES) permit.

5. Effectiveness in Either Increasing the Available Supply or Reducing the Projected Demand

Desalination technology is well proven and could effectively be used to lower salinity levels to produce potable water. However, the quantity of brackish water potentially available for desalination within the study area is presently unknown. Detailed hydrogeologic studies would be required for each location where desalination is contemplated. Based on a preliminary review of available information (DE&S, 2001), it appears that most of the brackish groundwater underlying the study area contains only slightly elevated TDS concentrations, mostly in the range of 1,000 to 5,000 mg/L TDS. The New Mexico State Engineer has defined “protectable underground water” as all waters in the State of New Mexico containing 10,000 mg/L TDS or less. Therefore, the brackish water within the study area would likely be classified as potentially potable under the State Engineer’s criteria. This in turn suggests that most of this brackish water would be subject to the same New Mexico water law governing the use of fresh water.

6. Environmental Implications

For desalination, the major environmental concern involves disposal of brine (highly concentrated saline water), which is a byproduct of all desalination processes. Alternatives for disposal of brine include (1) deep subsurface injection, (2) discharge to surface water stream or lake, (3) discharge to sanitary sewer, (4) disposal of brine in evaporation ponds, and (5) evaporation, crystallization, and disposal of solid salt in a special landfill (Winter et al., 2001).

- Deep subsurface injection wells would be considered Class V wells under the New Mexico Environment Department's (NMED) Underground Injection Control (UIC) Program. Obtaining permits for such wells could be costly and would require a hydrogeologic study to ensure that the proposed injection well(s) would not impact freshwater aquifers. Furthermore, drilling and maintenance of deep injection wells would also prove costly. For these reasons, deep injection of brines may not prove cost-effective.

- Likewise, direct discharge of desalination brine to surface water bodies would require an approved NPDES permit from NMED, and in all likelihood this option would not be permitted because it would result in degradation of surface water quality.

- Brine disposal to sanitary sewers probably would not require a permit providing the quantities were small enough to not cause significant salinity change in total flow to the wastewater treatment plant. For small desalination plants in communities served by sewers, this could prove the most economical option for brine disposal.

- Disposal of brine in lined evaporation ponds can be relatively inexpensive, especially where land is readily available. Brine evaporation ponds operating in Texas add costs of $0.05 to $0.25 per 1,000 gallons of fresh water produced (U.S. Congress, 1988).

- Crystallization and disposal of desalination salts in an approved landfill has become increasingly popular nationwide, in part due to the high technical and regulatory costs of surface or subsurface brine disposal. Salt crystallization can result in additional costs of $1.15 to $1.85 per 1,000 gallons of fresh water produced (U.S. Congress, 1988).

7. Socioeconomic Impacts

The Jemez y Sangre region of northern New Mexico is distinguished by its rural and agricultural character, predominantly Indian and Hispano population, localized land-based economies, and pockets of persistent poverty. In particular, its Indian and Hispano populations represent some of the most unique cultures in the world, products of a long history of continuous human habitation, adaptation, and cultural blending. Land-based Indian and Hispano cultures still thrive, carrying on centuries-old cultural traditions that include distinctive land-use and settlement patterns, agricultural and irrigation practices, natural resource stewardship practices, social relations, religious activities, and architecture. An example is the ancient acequia tradition, which is vital both as a sustainable irrigation system for subsistence and market agriculture and as part of the social glue that holds together rural communities.

The survival of these deeply rooted local traditions is essential for the continuity of rural culture and communities and, in turn, for the local tourism industry, which is built in large part upon the singular cultural and historical personality of the region. Preservation of these traditions is therefore an important consideration in determining the socioeconomic and cultural impacts of regional water planning.

Treating groundwater will have no greater socioeconomic or cultural impacts than the impacts that are occurring from the existing use of water. However, the acquisition of water rights to indirectly divert brackish water could put pressure on traditional communities. If saline water was piped in from outside the region, thereby making more groundwater available to more populous areas, this alternative would have the indirect socioeconomic and cultural benefit of reducing the desire for and pressure on upstream rural and agricultural surface water rights to support municipal and industrial needs. Depending on how and by whom treatment expenses are financed, this alternative may or may not reduce the cost of water for all users.

8. Actions Needed to Implement/Ease of Implementation

In general, implementation of desalination within a given sub-basin of the study area will require the following steps for the planning, design, and construction process:

- Hydrogeologic study to define water source (adequate quantity and quality)
- Legal study to assess water rights and permitting issues

- Conceptual design/feasibility study
  - Well field development
  - Pipeline/conveyance study
  - Treatability, blending, and wastewater disposal assessment
  - O&M considerations (e.g., workforce requirements)
  - Capital and annual cost estimates
  - Assessment of changes to distribution system and user rates
- Review and approval of selected design
  - Local, state, and federal approval
  - Public participation
  - Investigation of funding options
- Engineering design
  - Bench studies of water compatibility
  - Development of plans and specifications
  - Compilation of bid documents for approved alternative
- Construction (phased)
- Preliminary O&M
- System integration

For small-capacity plants that would serve smaller communities, many steps in the design process could be streamlined considerably by working directly with a vendor that offers off-the-shelf membrane filtration systems.

9. Summary of Advantages and Disadvantages

Advantages of desalination include:

- An increased quantity of potable water is available for use.
- Use of brackish water does not compete with other fresh water users.
- Technology is proven.

Disadvantages of desalination as a water management alternative include:

- The unit water costs are higher than the cost of traditional water sources.
- Costly disposal of waste brine or salt (e.g., landfill or deep injection) is required.
- Disposal of waste brine must comply with permitting requirements (UIC, NPDES, or New Mexico Discharge Plan)

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